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REPORT OF WORKSHOP ON RADIOLOGICAL EFFECTS OF NUCLEAR WAR; SCOPE-ENUWAR WORKSHOP; MOSCOW, U.S.S.R. MARCH 21-25, 1988

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Report of Workshop on Radiological Effects of Nuclear War[1]

SCOPE-ENUWAR WORKSHOP; MOSCOW, U.S.S.R
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The workshop on radiological consequences of nuclear war addressed specific issues that built on the foundation of the results that were published in the SCOPE-ENUWAR report (SCOPE-28) in 1986. The workshop began with a brief review of the major conclusions of that study.

From SCOPE-28

Global fallout calculations for a major nuclear war predict that the average 50 year unsheltered, unweathered external total body gamma dose levels would be about 0.15-0.20 Gy per person in the Northern Hemisphere, and about 0.005 Gy in the Southern Hemisphere. A maximum of 0.30 to 0.50 Gy is predicted for the latitude band from 30°N to 50°N. Peak values ("hot spots") using a grid size of 4° longitude by 5° latitude are of the order of 1 Gy, with higher values expected as a result of local precipitation events. Values estimated for the global population (50-year) dose are typically about 6×10^8 person-Gy. Additional calculations using conditions representing an atmosphere perturbed by the smoke emitted from fires generated by the nuclear war ("nuclear winter") indicate that the above dose assessments would be about 15% lower in the Northern Hemisphere and marginally higher (up to about 0.01 Gy) in the Southern Hemisphere compared to dose estimates assuming unperturbed atmospheric conditions. These results are consistent with the projection that smoke injections can increase vertical stability, inhibit precipitation, and increase interhemispheric transport. Global fallout is considered a second order effect compared to the biological impact of blast, thermal, and local fallout, the so-called direct effects.

Potentially lethal levels of local fallout can extend many hundreds of kilometers downwind of sites targeted with nuclear ground bursts. Calculations for the SCOPE scenario showed that about 7% of the land areas of the combatant countries were covered by fallout producing an unshielded external, gamma dose of 4.5 Gy in 48 hours. The corresponding figure for 1.0 Gy, a level associated with radiation sickness, would be a coverage of approximately 30% of the land areas. At distances removed from direct effects, shielding from structures could significantly mitigate these dose estimates. The targeting of civilian and military nuclear fuel cycle facilities has the potential of additionally contributing significantly to the burden of global and local fallout.

1This report was prepared by Prof. Charles S. Shapiro, chairman, with the vassistance of many participants of the workshop.

NEW WORK REPORTED IN MOSCOW

Local Fallout

In a paper presented by Ted Harvey, the graphical local fallout model used in the SCOPE/ENUWAR study, and its progenitor, KDFOC2, was compared to several other popular fallout models used in the U.S.A. These include the models SEER3, WSEG10, and DELFIC, as well as the analytical fallout model found in Glasstone and Dolan's classic book, "The Effects of Nuclear Weapons - 1977".

DELFIC is considered by many to be the standard in the U.S. against which other fallout models should be calibrated. Visual, graphical, and tabular comparisons of the results of the other models were made to DELFIC results for a hypothetical 1-Mt, all-fission, nuclear explosion. Some results were compared down to 0.1 Gy/hr dose rate at 1 hour after the explosion. Harvey found that KDFOC2 and the SCOPE model patterns compared extremely well with DELFIC patterns below 30 Gy/hr. WSEG10 and SEER3 compared less well. The Glasstone and Dolan model prediction comparisons were the worst. They substantially overpredict both the DELFIC downwind distances and area coverages for all dose-rate isopleths. At low yields, KDFOC2, SEER3 and DELFIC predictions were compared to Nevada Test Site measurements. When these results were reviewed, KDFOC2 was shown to be the superior model, with DELFIC second, and SEER3 a distant third.

Charles Shapiro reported on some recent calculations by Daugherty, Levi and von Hippel on "limited" nuclear attacks on strategic nuclear targets in the U.S. and the U.S.S.R. Their work utilized a range of values of $LD_{50/60}$, the Postol firestorm conflagration model as well as the blast model for direct effects, a range of wind conditions, the WSEG10 computer code for fallout contours, and a detailed target and population distribution with a related protection factor profile. Civilian fatalities are predicted to be of the order of tens of millions of people in each country. In their calculations, local fallout accounts for a significant share of total deaths. Shapiro pointed out that a similar study by Harvey et al. at the Lawrence Livermore National Laboratory, involving a counterforce-countervalue attack on the U.S., produced similar estimates of total fatalities, but a much smaller percentage attributed to fallout. The difference was in part attributable to the different fallout codes used; the study by Harvey utilized the KDFOC2 code.

Implications of Stragetic Arms Reductions on Fallout and other Effects

Projections of levels of radioactive fallout, blast and thermal effects, and the generation of smoke and soot from a nuclear war are sensitive to assumptions about the composition of the nuclear stockpiles as well as the assumed scenarios for a nuclear war. Recent arms control proposals would change these parameters. The paper presented by Charles Shapiro examined the implications of the proposed INF (Intermediate-range Nuclear Forces) treaty and START (Strategic Arms Reduction Treaty) on damage projections from a major nuclear war. It concludes that except for local situations in Europe, the INF reductions are likely to have negligible effects on estimates of global and local fallout, whereas the START reductions of approximately 50% in strategic weapons could result in reductions in the estimates of local fallout that range from significant to dramatic, depending upon the nature of the reduced strategic forces. Should a major war occur, projections of total fatalities from direct effects of blast, thermal radiation, and the generation of smoke leading to the phenomenon known at "nuclear winter", would not be significantly affected by the INF and START initiatives as now drafted. When one considers reductions in strategic weapons of 75%, the study indicates that a deterrence based on a second strike capability remains viable, but the projected destruction of military and industrial targets that are collocated with population centers begins to be reduced depending on the nature of the reduced forces. For reductions of 75% or greater, an increase in crisis stability seems possible.

Internal Dose

In a paper by Peterson, Shapiro and Harvey, calculations were presented of the contribution of internal dose in humans from the ingestion of food and water contaminated by local fallout resulting from a major nuclear war. The internal dose to an individual is sensitive to many factors that vary greatly depending on local circumstances. For this reason, a "users manual" approach was used, allowing interested researchers to conduct calculations using their own set of assumptions. Results of calculations were presented for case studies of individuals in 10 locations in the United States. Attention was focused on ^{137}Cs, ^{89}Sr, ^{90}Sr and ^{131}I, as evidence indicates that these four radioactive isotopes would contribute the largest share to the internal dose.

The case studies had variable external doses, shelter factors, availability of foods from nearby government distribution agencies, other foods available within local distances, and numerous other variables. The calculations showed that the ratios of internal to external dose vary from less than one to approximately 100 percent. Seven of the case studies have ratios less than 10 percent. The higher ratios result from the combined effects of a large shelter factor (reducing the external dose) and consumption of contaminated food for long periods (increasing the internal dose).

Atomic Bomb Dosimetry Reassessment for Hiroshima and Nagasaki

For the epidemiological study of survivors in Hiroshima and Nagasaki, a reassessment of atomic bomb doses have been achieved by a US-Japan Joint Research Group that constructed a new dosimetry system called DS86. In a paper by T. Maruyama, Y. Kumamota, and Y. Noda, and with additional contributions from T. Ohkita, it was concluded that neutron doses of the T65D dosimetry (1965) were reduced in both cities and gamma doses were increased in Hiroshima. Using the DS86 and the epidemiological data accumulated up to 1985, dose-effect relationships have been re-evaluated for acute and chronic damages to survivors. A dosimetric study on residual radiations from fallout and neutron-induced radioactivities on the ground in Hiroshima and Nagasaki have just been started on the basis of a new meteorological model.

Briefly, the differences between this new system (DS86) and the old (T65D) can be summarized as follows:

1. The DS86 free-in-air gamma dose increases somewhat in Hiroshima, but decreases in Nagasaki in comparison with the T65D.

2. The neutron dose decreases in both cities, to about 10% its former value in Hiroshima and 30% in Nagasaki.

3. The transmission factor for gamma rays in wooden Japanese structures is smaller, about 51% and 59% of the T65D value, on average, in Hiroshima and Nagasaki, respectively.

4. As a consequence, the average DS86 total shielded dose (the sum of shielded gamma and neutron doses) for those survivors exposed to 0.01 Gy and over decreases to 69% and 76% of the T65D values in Hiroshima and Nagasaki, respectively.

Health Effects of Thermonuclear War

Alexander Leaf and Takeshi Ohkita presented new material about health effects of thermonuclear war published since the first World Health Organization (WHO) Report of 1984 "Effects of Nuclear War on Health and Health Services". A summary of this work shows:

1. Fires rather than blast effects are likely to be the major cause of acute casualties following a nuclear war. The conflagration model, according to Postol and Daugherty et al. has been used to calculate the anticipated casualties rather than the overpressure model which previously has been the standard. Instead of the lethal area being defined as being at least subjected to 5 psi over-pressure (150 sq km), the area of an expected fire storm is used. For median atmospheric conditions combustible material within a 1 km radius of an air burst of 1 Mt. yield is expected to ignite almost simultaneously creating a mass fire. According to the modelling by Daugherty, Levi, and von Hippel, this would yield a lethal zone with a radius of 10 km from ground zero. In addition, within a 2 km wide penumbra encircling the lethal zone, the model assumes one-half the inhabitants would die and one-third would be injured. The effect of this change in estimating casualties is to expand the lethal area from 150 km^2 to 380 km^2 for a 1 Mt yield air burst. With uniform population density in the area targeted, the resultant mortality figures would increase by a factor of 2 to 3 compared to the older model. All the assumptions and uncertainties inherent in considering the combustible materials and the areas of conflagration are applicable to this modelling. While overall mortality figures increase with the use of the fire conflagration model, those attributed to fallout decrease. This is because some of the local fallout fatalities are shifted over to the prompt deaths category.

2. The $LD_{50/60}$ for ionizing radiation effects in humans has been reassessed for nuclear war conditions from the Hiroshima experience by Rotblat and Ohkita. They re-examined the position, shielding and survival of individuals in Hiroshima at the instant of the nuclear explosion. With

the assumption that all deaths occurring within 24 hours of the explosion were due to burns or blast and all subsequent deaths due to ionizing radiation, they calculated an $LD_{50/60}$ for bone marrow of 1.6 Gy, or a whole body surface dose of 2.2 Gy. However, with the newer Hiroshima dosimetry (DS86) (the new figures from the Radiation Effects Research Foundation (RERF) dosimetry), the bone marrow dose has been recalculated by Ohkita, to be 2.4 Gy and the corresponding body surface LD_{50} dose to be 3.4 Gy.

3. It has been realized by Greer and Rifkin that several aspects of thermonuclear explosions, combined with ionizing radiation or with each other, would suppress the immune system through a common action to reduce the ratio of helper to suppressor T-lymphocytes in humans. These aspects include:

a. burns and trauma
b. psychologic depression and bereavement
c. malnutrition
d. hard UV-B (290-320 nm)

These are all expected wide-spread effects of nuclear war and thus immunosuppression would be widespread. This would heighten susceptibility and worsen prognosis of the population to infectious diseases. Such diseases are thought to be rampant following a nuclear war because of an expected breakdown of sanitation. These immunosuppressive factors also interact synergistically with other injuries, i.e., burns and trauma, which will also be prevalent following nuclear war. The effect is to greatly worsen the prognosis of those victims of burns, trauma, infections, or radiation.

Mikhail Vilenchik presented a paper in which he estimated carcinogenic risks among nuclear war survivors. Synergistic effects between chemical pollutants and radiation could be quite strong, leading to potentially large human impacts. The sensitivity of infants and children to synergistic effects is especially acute. Andrey Yakovlev presented a mathematical formalism for the estimation of carcinogenic risk. V. Shevtchenko's paper discussed the genetic consequences of ionizing radiation on natural populations and communities.

Radioecology

Peter Van Voris presented a paper describing a user-friendly microcomputer digital simulation model to predict the long-term cycling of radiocesium in forest ecosystems. The model (RADFORET) used both radionuclide concentration in the soil compartment and rate of forest growth to control the movement into and cycling within the model. The availability of the radiocesium was controlled within the model by choosing the percent clay, cation exchange capacity and percent organic matter for the ecosystem being modeled. Forecasts of ^{137}Cs distribution in the linear donor-controlled model favorably compared with actual ^{137}Cs cycling after 30 years in forests in Oak Ridge, TN, and Savannah River, Georgia. This comparison provided a measure of model validity for additional simulations of projected long-term (~250 years) radiocesium cycling in coniferous forests around the Chernobyl nuclear reactor accident site in the USSR.

Rene Kirchmann presented a summary of the programme of the IVth International Symposium of Radioecology of Caderache on "The Impact of Nuclear Origin Accidents on Environment" (March 14-18, 1988). This included the following:

- --130 participants from 25 countries attended the Symposium
- --88 papers were presented of which 36 were concerned with the Chernobyl accident's impact on the environment. In particular, some "sensitive" ecosystems were identified (forests, shallow lakes, poor agricultural areas).
- --This symposium synthesized knowledge in these fields, and proposed new experimental programmes about accident situations, including specific physico-chemical forms.

Chernobyl

A major part of the workshop was devoted to a study of the nuclear accident at the Chernobyl reactor complex. This included a very interesting and informative visit to the site by a subset of the non-Soviet scientists participating in the radiation workshop.

The scientists who visited the Chernobyl reactor complex received an indelible impression of a response on an immense, even heroic, scale to the unprecedented accident at Reactor Unit No. 4. The details given in official reports were brought alive by the visits to the information center, through Reactor Unit 2 control room, the sarcophagus entombing Unit 4, the surrounding forest area, the deserted nearby town of Pripyat and the glasshouse experiments. They all illustrated the efficiency of the rescue operations and the dedication of the Soviet personnel.

The complex is now working with 3 operating reactors and 3000 plant personnel. The return to normal conditions is reflected in an average per person annual dose of 15 mSv for 1987, with only 2 people receiving more than 50 mSv. The ground area around unit 4, which had dose reates as high as 1000 Roentgens per hour after the accident, now showed only about 4.0 mR/h and 2 to 3 mR/h in the air above, using instruments carried by the visitors. This decontamination had been achieved by removing millions of tons of top soil to deep-pit burial. The adjacent forest had turned red from deposited material and the trees had also been cleared and buried. So far there has been no problems with contamination of ground water. The concrete sarcophagus appears to be containing the remaining core radioactivity.

The town of Pripyat had 50,000 inhabitants who were evacuated in 1500 coaches over 2 1/2 hours during the 2nd day following the accident, leaving only some stray dogs and small animals foraging for food. The buildings have been decontaminated externally. The town cannot be re-occupied while areas in the 30 km diameter zone still have local high levels of radiation. Outside this area, the army encampments remain and all movements in and out are rigorously controlled, including the 7,000 people brought into the zone in addition to the plant personnel. Medical surveillance for radiation effects on 5 million people in the surrounding area has been organized.

The scale of the operations emphasize the difficult problems which would follow nuclear attacks, with resources for rescue inevitably limited.

The magnitude of the environmental clean-up problems that the Soviet government has and will continue to face over the next several decades was staggering. A total of 3,000 km^2 of land has been excluded from public access. Of this approximately 1,000 km^2 of agricultural land has been contaminated to an extent that the land is unavailable for an undetermined extended time for growing crops and grazing livestock. Also, during the groups travel from Kiev to Chernobyl, as one approached the outskirts of the 30 kilometer exclusion zone, additional agricultural areas appeared to have been allowed to go fallow over the last two years. Within the tear-drop shaped 10 kilometer zone which received the highest levels of contamination (some spots within this area had experienced >1,000 Roentgens/hr) the coniferous forests that were damaged (i.e., red-topped scotch pine) from combined gamma and beta exposure, and possibly from chemical burns induced from fire suppressants which were poured into the reactor, were removed and buried in waste cribs. This amounted to approximately 500 hectares of the most highly contaminated forests which were primarily secondary growth scotch pines. Additionally, $5x10^6$ m^3 of the most highly contaminated soil was removed from this same area for disposal in these same waste cribs. These areas were then covered with sand and have been seeded with a rye or fescue grass.

The visit to Chernobyl was preceded by the presentation in Moscow of a number of papers analysing the accident. Sir Frederick Warner contributed a paper on ethical and environmental considerations relating to Chernobyl. After summarizing the main facts of the accident, the reactions to it, and the consequences in terms of global atmospheric pollution, he asserted that the disaster has underlined the responsibilities of top management and professional engineers, the need to promote a 'safety culture', the value of effective organization, the international exchange of experiences, and the role of the media in improving public information. In any nuclear emergency, he suggested that there are older engineers and scientists willing to volunteer their services, as exposure is of less consequence to them than it would be to younger staff members.

Helen ApSimon contributed a paper discussing the pattern of radioactive releases from Chernobyl based on long-range contamination patterns. She described the circumstances of the Chernobyl accident and the resulting release over the subsequent days deduced in part from data presented by Soviet scientists at a special meeting in Vienna in August 1986.

Observations of the spread of material complement such information to provide the best documented example ever available for an atmospheric release of dispersion and subsequent deposition out to long distances. This gives an opportunity to test our capabilities to analyze the processes involved and represent them in models. Despite uncertainties about the source terms, models have provided a picture of the dispersal of material which is broadly consistent with the observations over all distance scales. Attempts to work backwards to the emissions and their variation in time, by comparing model calculations with measurements, are generally within a factor 2 of the estimates given by Soviet scientists. However, the deposition is extremely patchy, and concentrated in areas of high precipitation that intercepted the airborne radioactivity even after long travel distances. In this respect detailed rainfall data is often a limiting factor in estimating the overall transport and dispersal. Vertical transport in frontal and other precipitation systems is also an important factor in the overall transport and dispersal. Modelling studies within the USSR provided good agreement with measurements on local levels of contamination in the vicinity of the Chernobyl plant based on meteorological data from the region.

Paul Gudiksen presented a paper on the Chernobyl source term, atmospheric dispersion, and dose estimation. The Chernobyl source term available for long range transport was estimated by integration of radiological measurements with atmospheric dispersion modeling, and by reactor core radionuclide inventory estimation in conjunction with WASH-1400 (U.S. Nuclear Regulatory Commission report "Reactor Safety Study") release fractions associated with specific chemical groups. These analyses indicated that essentially all of the noble gases, significant fractions of the volatile elements, and about 1% or less of the more refractory elements were released.

Atmospheric dispersion modeling of the radioactive cloud over the Northern Hemisphere revealed that the cloud generated by the initial explosion became segmented during the first day, with the lower section heading toward Scandinavia and the upper part heading in a southeasterly direction with subsequent transport across Asia to Japan, the North Pacific, and the west coast of North America. The inhalation doses due to direct cloud exposure were estimated to exceed 10 mGy near the Chernobyl area, to range between 0.1 and 0.001 mGy within most of Europe, and to be generally less than 0.01 μGy within the U.S.

The Chernobyl source term was several orders of magnitude greater than those associated with the Windscale and TMI reactor accidents, while the ^{137}Cs from the Chernobyl event is about 6% of that released by the U.S. and U.S.S.R. atmospheric nuclear weapon tests.

Henning Rodhe presented a paper with a meteorological analyses of deposition in Sweden. The paper contained a detailed description of the transport and deposition during the first few days of the radionuclides emitted during the first few hours following the explosion in the reactor. It highlighted the importance of vertical mixing in the atmosphere associated with convective clouds and frontal precipitation systems. For volatile nuclides, such as ^{137}Cs, occurring mainly as submicron sized aerosol particles, the main deposition mechanism is by precipitation. The Chernobyl plume reached Sweden in quite concentrated form. It there became incorporated in a precipitation system and a large fraction of the nuclides was deposited in central Sweden. The deposition of ^{137}Cs exceeding 120 kBq/m^2 in an area of about 100 km^2. Over Sweden the correlation was very high between total deposition of ^{137}Cs and rainfall amounts falling on 28-30 April. This study provided a clearcut example of the high degree of patchiness of deposition that could be expected from a major release of radionuclides into the atmosphere.

Tamoaki Yoshikawa presented a paper describing a numerical simulation of the global dispersion of radioactivity from Chernobyl. The large amount of radioactive pollutant emitted in the atmosphere by the nuclear accident in Chernobyl in April, 1986, was dispersed in the world. Numerical simulation of global scale dispersion of the radioactive pollutant was carried out by using an operational meteorological model of the Japan Meteorological Association. Calculated concentrations agreed well with the observations in many places in the world, including Japan.

A number of oral presentations were made regarding the modeling of radioactive distributions in water systems. One presentation by Mark Zheleznyak involved a study of the radionuclide distribution in the Kiev reservoir.

Lev Khitrov presented a list of 10 lessons learned from the Chernobyl accident that are of help in predicting the consequences of a war. These include a differing mix of isotopes, atmospheric injection patterns, source term time dependence, changing isotopic concentrations, the importance of "hot" particles, the checkerboard pattern of localized deposition, and the tremendous effort required for cleanup of contamination. His last lesson is that there should be no future wars.

RESEARCH RECOMMENDATIONS

The workshop concluded with a discussion of research recommendations for the future, and a proposal put forth by Helen ApSimon for a future workshop. It was clear that since publication of SCOPE 28, progress has been made on the topic of radiological consequences of nuclear war. Some areas, however, require further work. - A list of recommended topics follow (not in any priority order).

1. Effects of radiations, including beta rays, on biota.
2. Further work on implications of attacks on nuclear fuel cycle facilities, including military sources.
3. Continued research on pathways of radionuclides through the biosphere.
4. Ecological conditions facing survivors following a nuclear war.
5. The role of precipitation scavenging in depositions.
6. Continued work on evaluation of local fallout codes; especially at lower dose levels.
7. Continued research on the extrapolation of the Japanese experience to a modern nuclear war situation.
8. Early time measurements of radioactivity in the area localized around Chernobyl.
9. The quantization of synergisms in human health effects.
10. The significance of low doses of radiations on large populations.
11. The connection between atmospheric electrical effects (for example, lightning) and radioactivity in the atmosphere.

A PROPOSAL FOR A WORKSHOP

Helen ApSimon put forth a proposal after our visit to Chernobyl. The scientists who visited Chernobyl were extremely impressed with the tremendous effort devoted to the tasks of decontamination, and the enormous progress already achieved. While appreciating that priority must be given to returning the contaminated zone to normal conditions of operation and activity, it was recognized that opportunities are also available to obtain valuable scientific data. In this respect many of those visiting Chernobyl recognized the possibilities of comparing a real situation with experiments which they and their colleagues are conducting in artificial conditions. Many of these possibilities are doubtless being investigated already by Soviet scientists. But there may be some additional measurements of great scientific value, which could be carried out relatively easily, and on which international collaboration on the techniques used could be advantageous.

Prof. ApSimon therefore proposed that a workshop should be held at which scientists working in the interdisciplinary fields of environmental radioactivity should come together to consider what measurements are of outstanding scientific interest and priority following Chernobyl, and how these might be obtained. Soviet scientists could then decide which of these ideas should be pursued, and take advantage of international collaboration where appropriate.

When this proposal was discussed at the Moscow SCOPE-ENUWAR workshop it was recognized that there were 2 distinct aspects:

1. scientific data which can still be gathered, now and in the future
2. information on data already available and research already in progress

Two suggestions were put forward to aid communication of information. First a list of measurements of scientific interest which might already be available should be prepared. Due to the extremely difficult situation and resources required in the aftermath of the Chernobyl accident, it is recognized that only some of this information has been recorded, but this list would help in its communication. Secondly, a review of research in the Soviet Union already undertaken and reported on would be extremely valuable. These would provide a good basis for suggestions on potential future research and international collaboration.

PARTICIPANTS IN THE RADIATION WORKSHOP

Chairman: Professor Charles S. Shapiro
San Francisco State University and
Lawrence Livermore National Laboratory, U.S.A.

Co-Chairman: Professor Eugen Komarov
Institute of Roentgenology and Radiology, Leningrad, U.S.S.R.

Paul H. Gudiksen	U.S.A.	Henning Rodhe	Sweden
Ted Harvey	U.S.A.	Yuri Svirezhev	U.S.S.R.
Lev Khitrov	U.S.S.R.	Peter Van Voris	U.S.A.
Rene Kirchmann	Belgium	Mikhail M. Vilenchik	U.S.S.R.
Alexander Kuzin	U.S.S.R.	Sir Frederick Warner	United Kingdom
Alexander Leaf	U.S.A.	Andrej Yakovlev	U.S.S.R.
Takashi Maruyama	Japan	Tomoaki Yoshikawa	Japan
Takeshi Ohkita	Japan	Mark Zheleznyak	U.S.S.R.

LIST OF PAPERS PRESENTED AT THE MOSCOW RADIATION WORKSHOP

ApSimon, H.M. and Wilson J.J.N., "The Pattern of Radioactive Releases from Chernobyl Based on Long-range Contamination Patterns."

Gudiksen, P.H., Harvey, T.F., and Lange, R., "Chernobyl Source Term, Atmospheric Dispersion, and Dose Estimation."

Harvey, T.F., "Prospectives on the Local Fallout Model Used in the SCOPE/ENUWAR Study."

Khitrov, Lev, "Radioactive Contamination of the Biosphere in a Non-Nuclear War: Lessons from Chernobyl."

Kimura, F. and Yoshikawa, T., "Numerical Simulation of Global Scale Dispersion of Radioactive Pollutants from the Accident at the Chernobyl Nuclear Power Plant."

Maruyama, T., Kumamoto, Y., and Noda, Y., "Atomic Bomb Dosimetry in Hiroshima and Nagasaki."

Persson, C., Rodhe, H., and De Geer, L-E., "The Chernobyl Accident - A Meteorological Analysis of How Radionuclides Reached and Were Deposited in Sweden."

Peterson, K.R., Shapiro, C.S., and Harvey T.F., "Internal Dose Following a Large-Scale Nuclear War."

Shapiro, C.S., "Radioactive Fallout Projections and Arms Control Agreements: INF and START."

Van Voris, P., Cowan, C.E., Cataldo, D.A., Wildung, R.E., and Shugart, H.H., "Modeling the Dynamics of Long-Term Cycling and Storage of ^{137}Cs in Forested Ecosystems."

Vilenchik, M., "Biological Basis for Estimation of Carcinogenic Risks Among Nuclear War Survivors" (in Russian).

Warner, F., "Chernobyl - Ethical and Environmental Considerations."

Yakovlev, A., "Nonparametric Estimation of Population Carcinogenic Risk" (in Russian).

Zheleznjak, M., "Modeling of Radionuclide Distribution in the Kiev Reservior" (in Russian).